(12) UK Patent Application (19) GB (11) 2 393 142 (13) A

(43) Date of A Publication 24.03.2004

(21) Application No: 0222013.5

(22) Date of Filing: 21.09.2002

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(51) INT CL^7:
B04B 9/08

(52) UK CL (Edition W):
B2P P10C3B1D P10C3B3 P9C
F2W W010 W038 W040 W232 W246 W368 W424

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GB 2069727 A DE 003409112 A1
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(58) Field of Search:
UK CL (Edition V) B2P, F2W
INT CL^7 B04B, F16D, F16H
Other: ONLINE: WPI, JAPIO, EPODOC

(54) Abstract Title: **Viscous clutch for decanter centrifuge drive mechanism**

(57) A decanter type centrifuge comprises a rotatable bowl 1 and a helical screw conveyor 2 journalled within the bowl. A drive mechanism is provided such that the bowl and screw may be driven at different speeds, with the screw being driven at a speed which is variable in response to an amount of solids collected within the bowl. A motor 11 drives the bowl and the screw, the screw being connected to the motor via a viscous clutch mechanism 8 and a belt transmission 10. The viscous clutch is designed such that torque is transferable therethrough. The clutch comprises a series of interleaved plates 104, 105 which are separated by a gap which is filled with a variable viscosity fluid such as silicone oil. When the torque increases the oil heats up, increases in viscosity and slip decreases and vice versa. In order to control this automatic feedback mechanism the outside of the clutch is fitted with a cooling arrangement 18. Instead, to heat the oil, a piston 113 is used to compress the interleaved plates, thus pressurising the oil and in a closed system, thereby heating it. When less torque is needed, the piston is withdrawn and the pressure on the fluid lessens and it is cooled by the cooling arrangement allowing the slip to increase and the torque to thereby descrease.

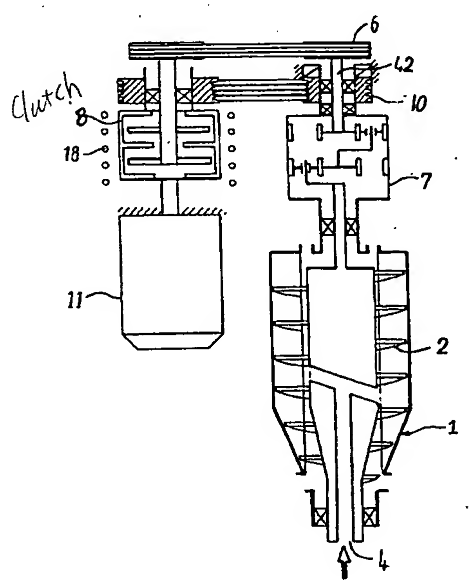
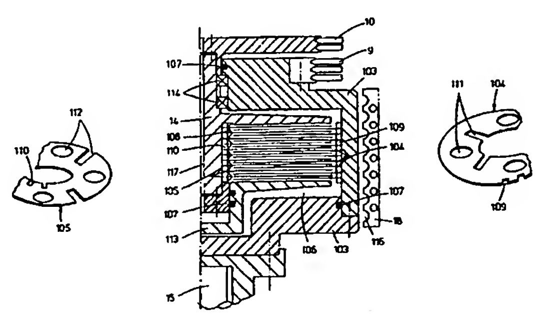


FIG.2



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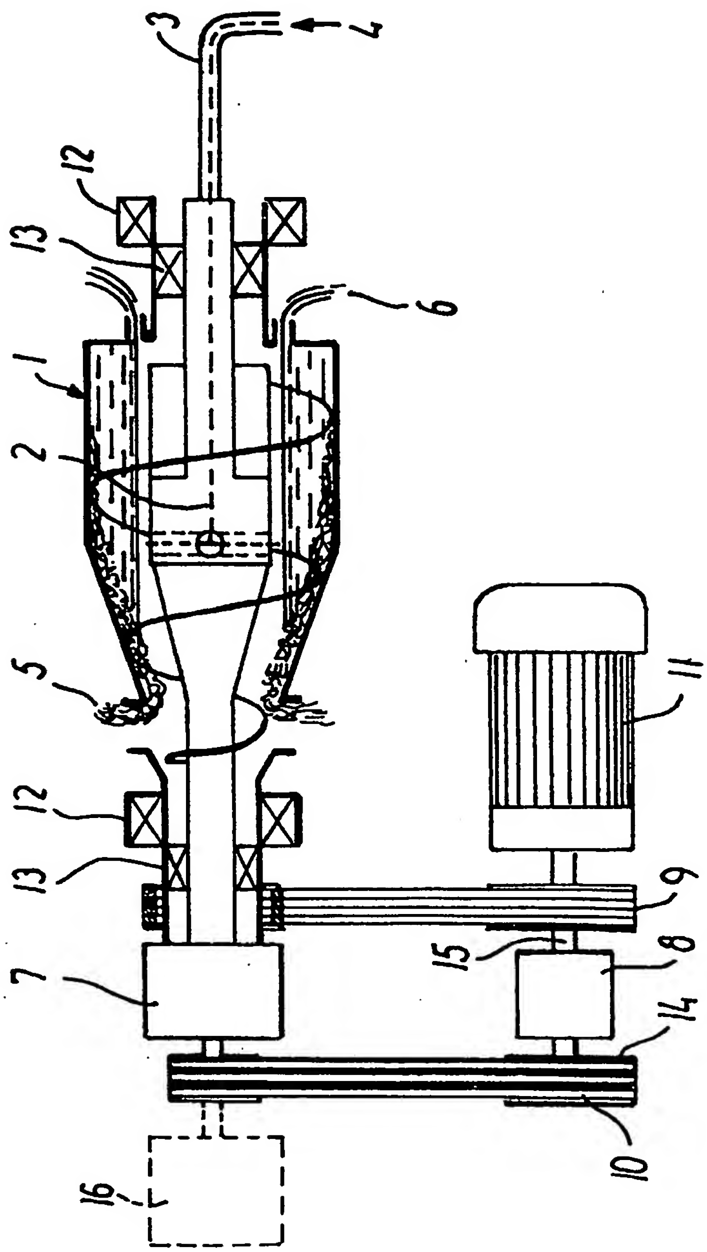


FIG.1

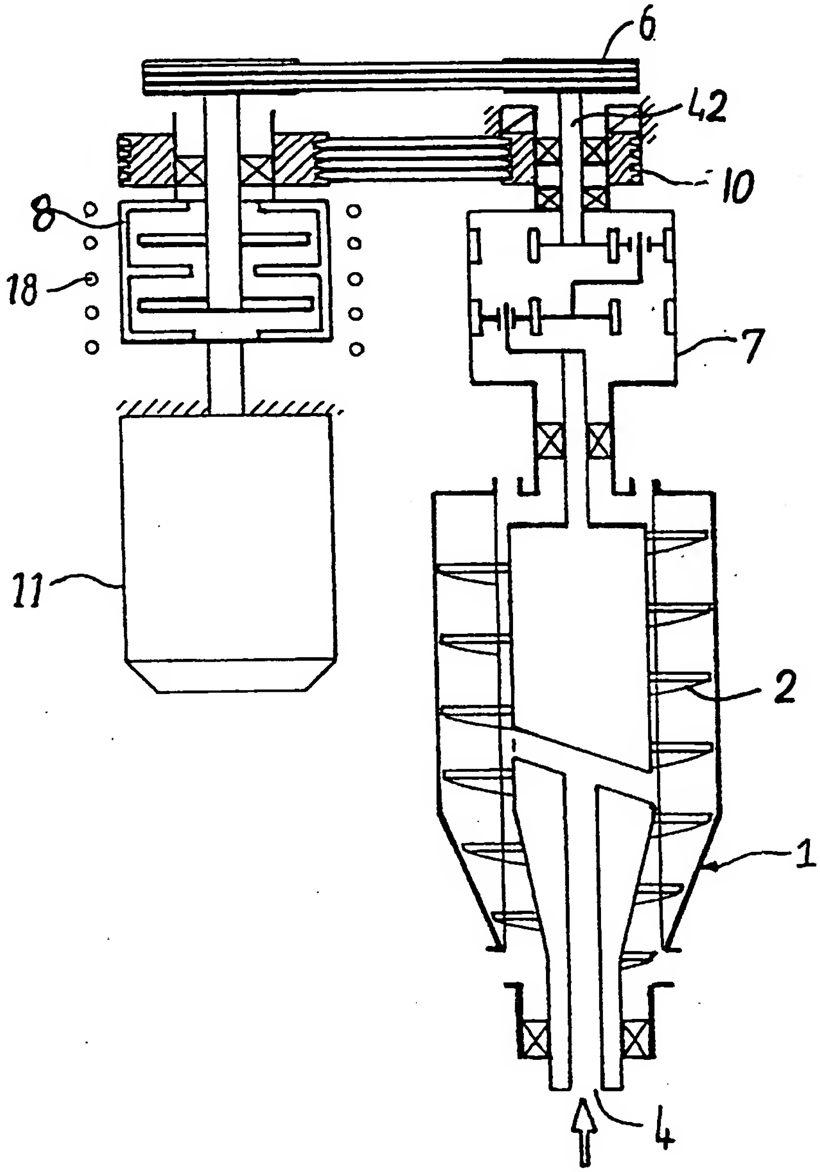


FIG.2

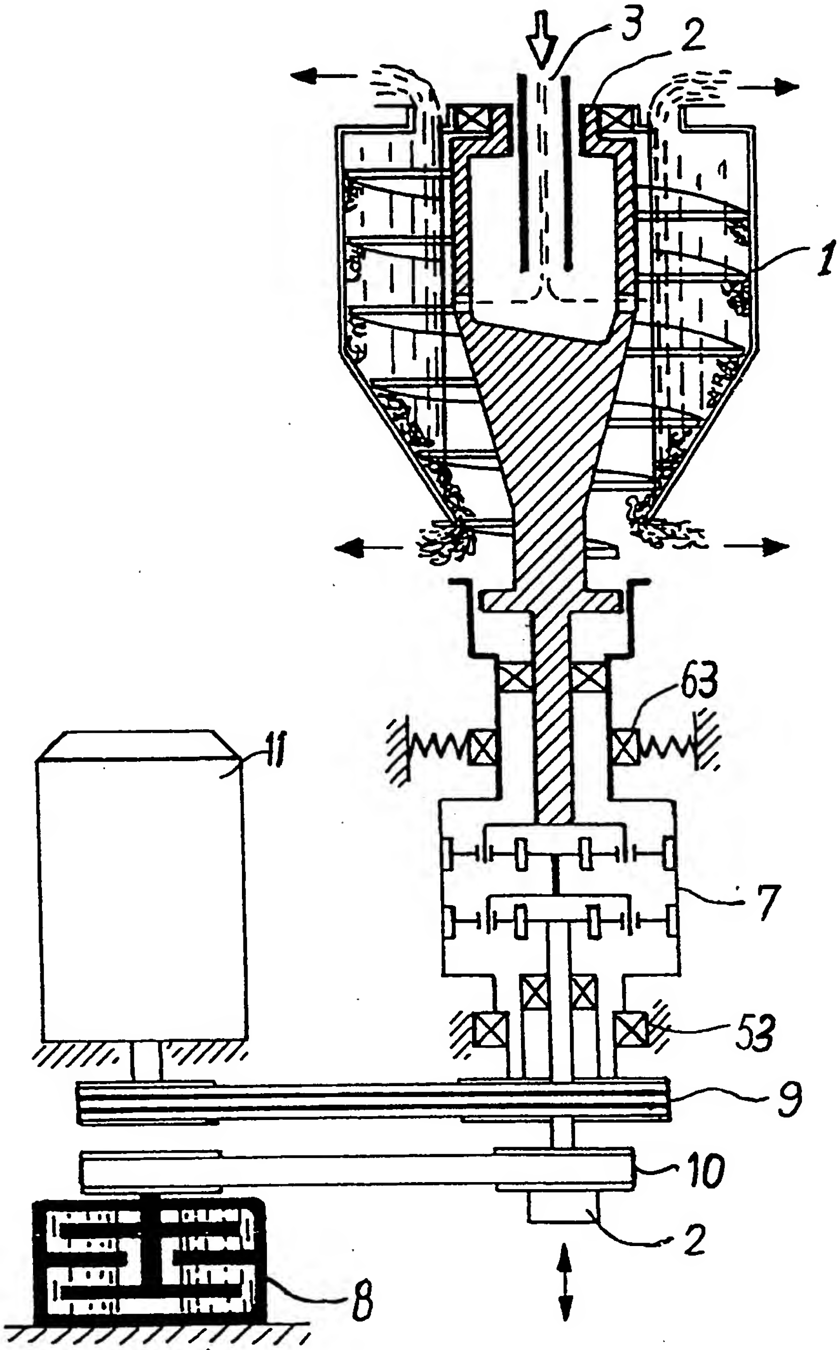


FIG.3

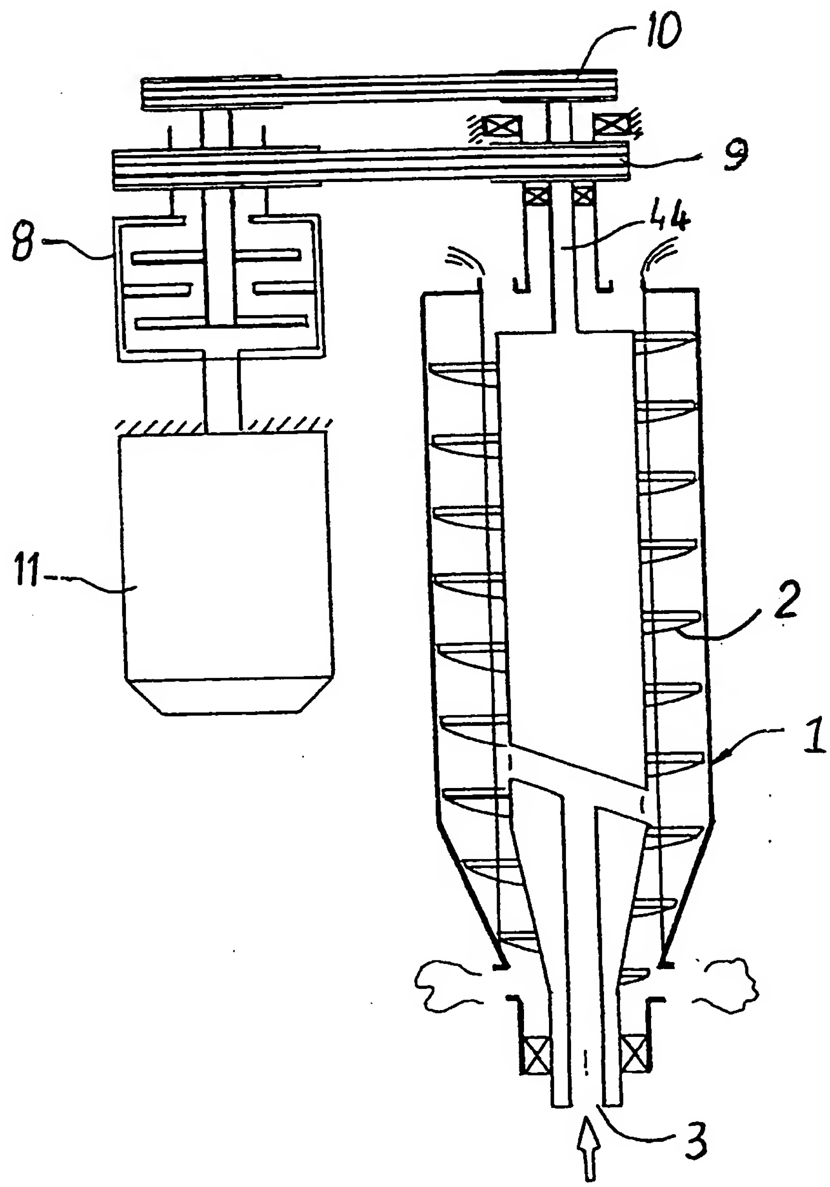
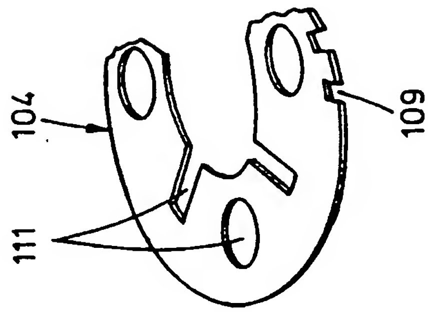


FIG.4



104
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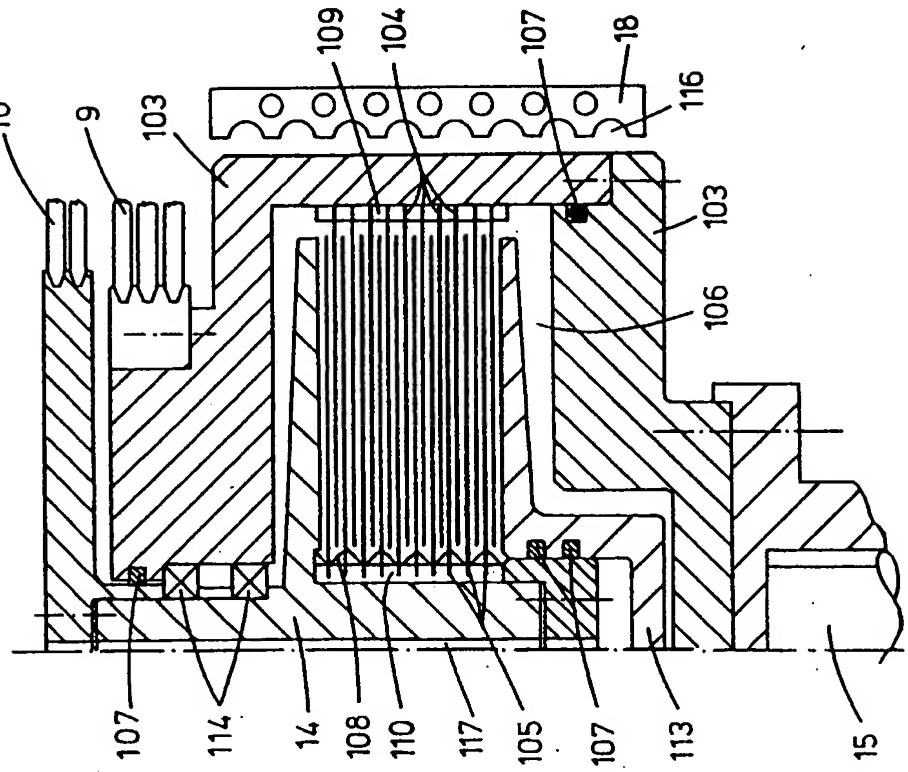
111



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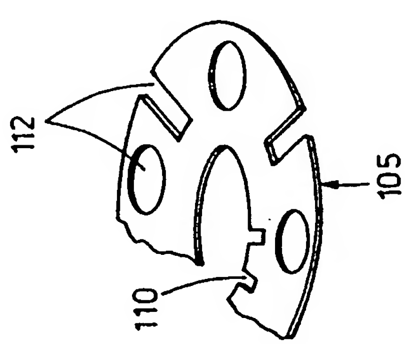

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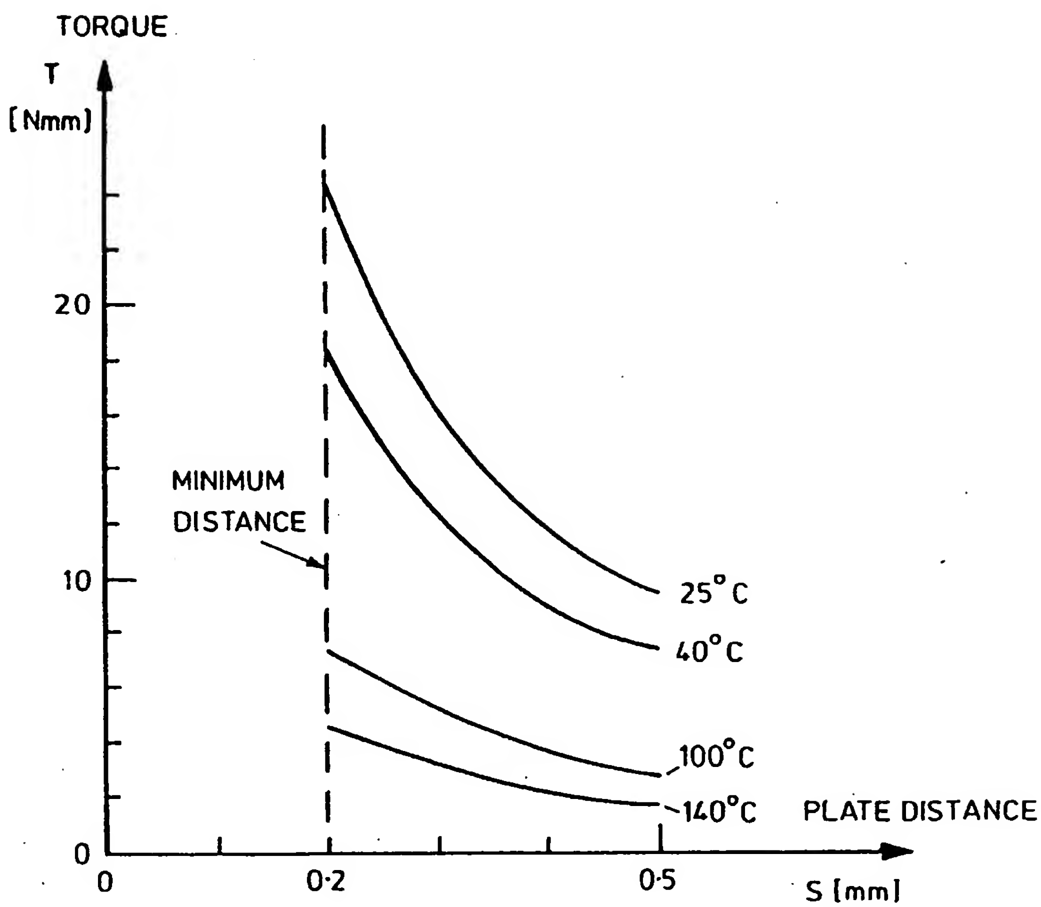
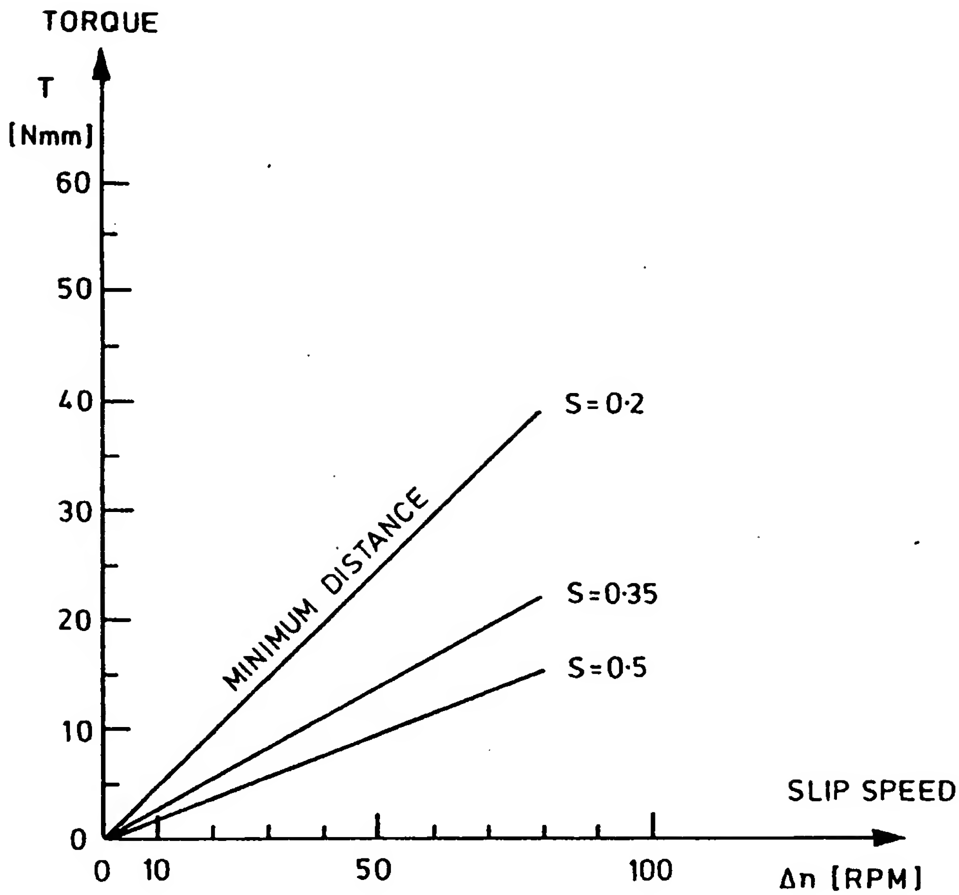


TORQUE – PLATE DISTANCE CHARACTERISTIC AT SAME RELATIVE PLATE SLIP SPEED



TORQUE – SLIP SPEED CHARACTERISTIC AT SAME TEMPERATURE

Title of the Invention

Centrifuge

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Field of the Invention

The present invention relates to a centrifuge, such as a decanter, comprising a rotatable bowl drivable at a first rotational speed, and a helical conveyer rotatably journalled within the bowl and drivable at a second rotational speed.

Background of the invention

Centrifuges operate as separators by means of a highly intense gravity field created by the rapid rotation of a bowl. Solids suspended in liquid fed into the bowl will fill the cavity of the bowl as an annular volume and be separated, the higher density parts (ie solids) assembling at the inside of the bowl shell, while lighter parts (ie water, oil) will assemble towards the axis of rotation.

Conveying centrifuges have a conveying means, ie a helical conveyer, mounted inside the bowl to convey the separated solids towards one end of the bowl where they are discharged through ports or nozzles, whilst the clarified liquid(s) flows off to separate outlets away from the solids outlets.

Conveying centrifuges (ie decanters) work in separation processes for clarification, dewatering or concentration, wet classification, solid-liquid extraction and such like processes.

Such a helical conveyer rotates within the bowl shell and in the same direction, and at a speed slightly different from that of the bowl shell. The differential speed is referred to as the scrolling speed.

In order to control the degree and quality of the separation done by the centrifuge, the bowl speed, the scrolling speed, or the inflow can be varied.

For very stable processes, the scrolling speed can be kept constant. Such centrifuges have a simple conveyer drive comprising a cycloid (ie planetary) type of gear transmission between the conveyer and the bowl, with the reaction member (ie sun wheel shaft) fixed to the machine frame. In case of torque overload a weight cell releases the fixture, and the centrifuge can be stopped, cleaned and restarted.

As an improvement to this, the reaction member may be driven by a fixed ratio pulley transmission, thus giving a means of changing the scrolling speed, when the centrifuge is at a stand-still by changing of pulleys.

Over the years, a wide variety of variable scrolling speed drives have been developed, comprising types depending on the gear transmission concept (ie variable hydraulic or electric motors or brakes attached to the reaction member) and pure scroll drive systems, where the torque and scrolling speed is generated by a hydraulic motor mounted onto the bowl and rotating with it.

Conventionally, the scrolling torque for variable scroll drives is employed as the command variable in a feed-back control system made up to control the scrolling speed in such a way as to ensure the flexibility of the centrifuge operation over a wide range of conditions at a simultaneous optimization of the results pertaining to separation engineering.

For such a control, the scrolling torque is the most important variable, because for solid matter transport, the torque is a statement of the degree of loading of the machine with solid matter and the amount thereof in the draining/drying/compression stage.

Keeping the centrifuge as close as possible to the point of plugging with solids without having contamination of the clarified liquid has proven in many applications, ie dewatering, to be the best operational condition. As the plugging condition is approached, the scrolling torque increases as a result of the higher loading with solids in the conveyer. If there is a flexibility in the control system, this will cause the scrolling speed to decrease, causing the centrifuge to get even closer to the plugged condition, eventually with the result that the machine has to be stopped and cleared of solids.

In a conventional control system, a signal proportional to an increase of the torque is fed back to the control circuit, which reacts by increasing (the torque and) the scrolling speed, until the centrifuge has cleared an adequate amount of solids out of the bowl, thus decreasing the solids loading of the system and moving away from the plugged condition. When the torque decreases as a result of lower solids loading, the scrolling speed decreases again, and the cycle can repeat itself.

Object of the invention

A basic object of the invention is the provision of an improved centrifuge such as a decanter of the aforementioned kind which avoids the exemplified complexity of the prior art and accomplishes an optimal automatic control under all possible operating conditions.

Summary of the invention

According to the present invention, there is provided a centrifuge, such as a decanter centrifuge, comprising a rotatable bowl drivable at a first rotational speed, and a helical conveyer rotatably journalled within the bowl and drivable at a second

rotational speed, characterised in that the helical conveyer is in power transferring connection with a fluid coupling comprising a housing containing first and second coupling parts, between which parts a torque is transferable through slip via a fluid in the coupling, by which arrangement the slip can be arranged to decrease while the torque is increasing, and vice versa, under certain controllable operating conditions.

Advantages of the Invention

When a difference in rotational speed occurs between the input and output shafts, the viscous shearing of the fluid works to transmit torque. The shearing action will cause the temperature in the fluid to rise, and the fluid will expand proportionally.

With a piston and spring embodiment the fluid coupling exhibits very low torque capacity at low shear rates, and at the same time assure a high-torque response in case the shear rate increases.

When the shearing rate is exceeding a certain value, the heat generated by the shear causes the fluid to expand, and the pressure inside the housing rises. At very high pressures, the viscosity of the fluid increases considerably, causing the resistance between the two sets of plates to increase, hence the torque capacity increases.

The fluids used are hydraulic oils having a viscosity dependance of temperature as low as possible, a high thermal expansion rate, and a high viscosity dependance of pressure (typically, the viscosity will double at every 300 bars pressure increase). This is often found in silicone type oils.

When exhibited to an increase in shear rate, the heat generated will stay in the oil and plates causing the temperature to rise. If the shear rate stabilises at a

given level, the resistance torque generated in the coupling will stabilise, when the cooling of heat away from the surface of the coupling is equal to the heat generated in the fluid and transported to the (cooled) wall. When the shear rate decreases, the equilibrium between (lower) generated heat and the cooled-away heat will cause the torque generated by the coupling to decrease, but this will only happen after a certain delay, given by the time that it takes to cool the fluid and plates down to a new, stable level.

If the shear rate increases to the level where a pressure is generated inside the coupling compartment, the pressure creates a condition in the coupling that brings the plates to get very close to each other and transmit a high torque for a period, limited by the shear rate and the cooling properties of the coupling wall.

When this occurs, the torque resistance between the two shafts increases very rapidly, and it will decrease from the top value only at a comparatively slow rate, depending on the cooling of the liquid inside the compartment.

A method of control not tested in practise, but supported by the above theory, would be to inject or extract oil under varying pressure to/from the compartment during operation, thus giving access to a very precise control of the occurrance of the high-torque reaction.

This kind of behaviour fits very well with the above described control behaviour of a conventional feed-back control system. It is, however, not depending on a complicated and vulnerable control circuit as found in conventional systems, be they of hydraulic, electrical or magnetic nature.

Preferred or Optional Features of the Invention

The fluid coupling is connected to a drive shaft of the helical conveyer via a belt transmission.

The fluid coupling is connected to a reaction member of a cycloid transmission.

The fluid coupling is connected to a reaction member of the helical conveyer, without a gear transmission.

The first coupling part comprises a first set of disc-shaped plates having central openings attached non-rotatably to the inside of the housing and having equal distances, and a second coupling part comprising a second set of disc-shaped plates attached non-rotatably to a rotatable shaft protruding coaxially through the central openings of the first set of plates and having equal distances, by which arrangement the two sets of plates are mounted alternately in the axial direction having basically equal distance between plates, characterised in that the inter-plate distances of one set of plates is larger than the thickness of the plates of the other set of plates, and in that the first and/or the second set of plates are attached in an axially displaceable manner to the housing respectively to the shaft.

The inner or the outer plates of each part are separated by springs in such a way that the distance between at least one of the sets of plates are kept at equal distances to each other.

The plates are alternately splined to input and output shafts.

The fluid coupling is fully or partly filled with a viscous liquid with high viscosity index and high coefficient of thermal expansion, such as silicone oil.

The characteristic of the fluid coupling is controlled and varied according to a preset optimization pattern through the control of the temperature of the fluid

coupling and the fluid contained therein, by use of a cooling medium such as air, liquid, or liquid mist, applied onto the outside faces of the fluid coupling.

The plates are enclosed in a sealed compartment capable of withstanding high internal pressures.

The plates are perforated to ease the exchange of fluid between the plates.

A piston mechanism is provided to compress the springs, when the fluid expands.

Control of the torque characteristic of the fluid coupling is provided by a pressurising system connected to a sealed-off coupling housing containing fluid and air, giving access for the addition or removal of fluid and/or air during operation, said pressurising system being connected to rotating as well as to stationary fluid couplings, directly or indirectly, by appropriate means.

Control of the torque characteristic of the fluid coupling is provided by a piezo-electrical actuator pressurising system connected to a sealed-off coupling housing containing fluid, giving access to pressurising of the system by means of electrical signals being transferred to rotating as well as to stationery fluid couplings, directly or indirectly, by appropriate means.

A control input signal to controlling equipment for the control of the fluid coupling characteristic is a reading of the speed of the conveyer, or the speed of the conveyer relative to the bowl.

A torque overload safety device is mounted between the fluid coupling and a reaction member of the conveyer drive transmission.

Brief description of the Drawings

The invention will now be described in greater detail, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a general arrangement of a decanter centrifuge with viscous coupling scroll drive.

Figure 2 shows an arrangement of a vertical decanter centrifuge with one main bearing and a viscous coupling scroll control.

Figure 3 shows a decanter centrifuge arrangement similar to the arrangement of a conventional disc separator with a viscous coupling scroll control.

Figure 4 shows a decanter centrifuge arrangement similar to the arrangement of Figure 2, where the coupling pulley system is tuned to work directly on the scroll shaft.

Figure 5 shows a torque transmission characteristic for a viscous fluid coupling device.

Figure 6 shows details of a viscous fluid coupling device.

In Figure 1 is shown a general arrangement of a decanter centrifuge with viscous coupling scroll drive, comprising a bowl 1 rotatably supported by bearings 12, and a helical conveyer 2 mounted therein, supported by bearings 13. At one end a shaft extending from the conveyer 2 is connected to the bowl 1 through a cycloid transmission 7, the reaction member of which is connected to a pulley transmission 10 and the input member 14 of a viscous coupling 8. The bowl 1 is driven by a motor 11 via a pulley transmission 9 providing a fixed speed of the bowl 1. An output member 15 of the viscous coupling 8 is connected to the motor shaft and the drive pulley and rotates at the same speed as these.

The ratio of the pulley arrangement 9 and the ratio of the pulley arrangement 10 are made such that the speed of the viscous coupling input member 14 is higher than the speed of the input member 15. An overtorque protection in the form of a torque clutch 16 may be mounted in connection with pulley drive 10 to protect the cycloid transmission against mechanical overloads (ie from viscous coupling seizure).

By this arrangement the conveyer 2 is rotated within the bowl 1 at a speed slightly different to that of the bowl 1, thus creating a screw conveying action towards the conical end of the bowl 1 to any matter deposited onto the inner wall of the bowl 1. The conveying action requires quite a high driving torque which is provided by the cycloid transmission 7. A number of different cycloid transmission types may be used for this purpose, ie a 2-train planetary gear transmission.

The decanter centrifuge functions in the following, conventional way:

The slurry or suspension 4 that is to be separated is fed to the centrifuge through a feed pipe 3 and a feed chamber in the interior of the conveyer. By centrifugal force, the feed is contained within the bowl 1 forming a liquid annulus, from which the solids particles are precipitated towards the inner face of the bowl 1 forming a cake 5, which is subsequently conveyed towards the conical end of the bowl 1 by the conveyer 2. Here, the cake dewaters during passage of the dry part of the bowl and leaves the centrifuge through openings in the bowl wall. At the other end of the bowl 1 the cleaned liquid 6 leaves the bowl 1 through another set of openings.

As the cake content in the bowl 1 increases, then, in accordance with the invention the torque on the cycloid transmission reaction member and pulley transmission 10 increases, causing the slip velocity in the viscous coupling 8 to

increase, in turn causing the viscous coupling to control the conveyer speed relative to the bowl in such a way as to stabilise the cake content, as explained above.

An example showing values of speeds, ratios etc is given in Figure 2, in which is depicted an arrangement of a vertical decanter centrifuge with a viscous coupling scroll control, comprising a helical conveyer 2 having a speed of, say, 5990 rpm, a bowl 1, having a speed of 6000 rpm, driven by an electrical motor 11 of speed 3000 rpm through a belt and pulley system 10 having a ratio of 2:1, and a planetary gear transmission 7, shown as a 2-stage planetary gear of transmission ratio 1:100 between the bowl attachment and the reaction sun wheel 42. (If the gearbox is kept stationary at the housing, one turn of the conveyer attachment will require 100 turns on the reaction sun wheel).

The reaction sun wheel 42 is arranged to have an operational setpoint speed of 5000 rpm though interaction with the viscous coupling 8 turning at 3000 rpm via a belt and pulley drive 10. If the required reaction torque is occurring at a slip velocity of 100 rpm, the belt and pulley transmission ratio should be chosen at 5000/(3000+100) = 1.61

A forced cooling system 18 is arranged around the viscous coupling 8 in order to provide adjustment of torque level, relative speed, and torque relaxation through temperature control. This system may be using air or water as the cooling medium, depending of the required cooling rates.

The gear wheel arrangement of the planetary gear 7 and the interior of the viscous coupling 8 are sketched to show orientation and attachments.

The feed enters the centrifuge from below through a seal arrangement (not shown).

In Figure 3 is shown a decanter centrifuge arrangement similar to the arrangement of a conventional disc separator. The bowl 1 has an internal helical conveyer 2, connected through the gear transmission 7 (shown as a planetary gear transmission) incorporated into the drive shaft. The drive shaft is driven by a belt and pulley transmission 10 and supported by a (spherical) support bearing 53, taking care of the axial thrust from the weight of the rotor, and by a spring-supported second bearing 63 for stabilisation of the rotor in case of unbalance from uneven cake build-up or sea-swell motions. A feed inlet pipe 3 is attached to the frame or chutes for assembling the discharged cake and liquid(s) (not shown).

Cooling may be added as water jacket cooling, if necessary.

In Figure 4 is shown a decanter centrifuge arrangement similar to the arrangement of Figure 2, with a direct viscous coupling scroll drive. In this case the coupling pulley transmission 10 is tuned to work directly on the scroll shaft 44, providing the full scrolling torque, which is only possible for small torques that are able to be transferred by belts or the like, and the total scrolling power (internal torque times bowl speed) is absorbed and cooled away by the coupling 8, increasing the performance requirements of the viscous coupling to a large degree. However, for small centrifuges, this may be feasible, as it makes the design very uncomplicated and provides the very attractive self-controlling scroll drive system to small centrifuges.

In Figure 5 is shown details of a viscous fluid coupling device 8, comprising input shaft 14 splined at 110 with belt pulley 10, output shaft 15 connected to belt pulley 9, and housing 103 with piston 113. The input shaft 14 is supported in bearings 114 relative to the housing 103. An aperture 117 in the input shaft 14 secures the freedom of the piston to move relative to the input shaft without trapping

air. The housing 103 is pressuretight sealed against the shaft 14 and piston 113 by means of seals 107, and the housing is splined internally to engage splines 109 at outer rim of outer plates 104 (shown enlarged to the right of Figure 5) with holes or slits 111 and movable in the axial direction between inner plates 105. Inner plates 105 (shown enlarged to the left of Figure 5) with holes or slits 112 engage input shaft 101 at splines 110. The distance between the inner plates 105 is controlled by springs 108. The pressuresealed compartment 106 is filled with (silicone) oil. The drive belts 10 and 9 are differing in such a way that when the output shaft 15, which is connected to the drive motor (not shown) rotates, a differential movement between the plates 104, 105 is taking place. If the shear rate in the oil between the plates increases, the temperature increases and the oil expands. The cooling arrangement 18 has spiralling air grooves 116 and removes heat to keep the shear rate at a stable level by cooling the outside of the housing 103. At increasing differential movement, the piston 113 moves to compress the springs 108 and decrease the distance between the plates 104, 105. When springs 108 are almost totally compressed, the plates 104, 105 are very close and the shear rate at its maximum, causing the temperature to rise, and because the springs are not active any more, the pressure in the compartment rises. This causes an increase in viscosity and a further rise in resistance between the plates 104, 105, which again causes the scrolling torque and subsequently the scrolling speed to increase. As heat is dissipated through the housing walls, the torque reduces, and the scrolling speed will reduce accordingly and stabilise the differential movement as well.

In Figure 6 is shown a torque transmission characteristic for a viscous fluid coupling device. The torque transmitted by the device is shown as a function of the

plate distance at different fluid temperatures, equivalent to different viscosities of the fluid.

In Figure 7 is shown a torque transmission characteristic for a viscous fluid coupling device. The torque transmitted by the device is here shown as a function of the slip speed at different plate distances.

All the illustrations above are showing viscous couplings mounted onto stationary or low speed members. The background of this is that any mass or length-adding feature that can be removed from the rotor will ease the design of this to achieve higher performance, as mass or extra length will tend to lower the upper limit of speed resulting from closeness to or passage of critical frequencies. Added to this, there is a tendency of the fluid coupling device itself to have varying performance, depending on rotational speed, and this tendency increases at higher speeds.

Apart from this, there is nothing to prevent the combination between a viscous coupling and a gear transmission to be mounted onto the rotor itself.

The embodiment of a centrifuge with a viscous fluid coupling to regulate the scrolling speed of the helical conveyer connected to a reaction member of the helical conveyer, without a gear transmission, is only valid for very small centrifuges, but will be able to change the competition of small decanters against small disk separators to the advantage of the decanters.

CLAIMS

1. A centrifuge, such as a decanter centrifuge, comprising a rotatable bowl drivable at a first rotational speed, and a helical conveyer rotatably journalled within the bowl and drivable at a second rotational speed, characterised in that the helical conveyer is in power transferring connection with a fluid coupling comprising a housing containing first and second coupling parts, between which parts a torque is transferable through slip via a fluid in the coupling, by which arrangement the slip can be arranged to decrease while the torque is increasing, and vice versa, under certain controllable operating conditions.

2. A centrifuge as claimed in Claim 1, characterised in that the fluid coupling is connected to a drive shaft of the helical conveyer via a belt transmission.

3. A centrifuge as claimed in Claim 1, characterised in that the fluid coupling is connected to a reaction member of a cycloid transmission.

4. A centrifuge according to Claim 1, characterised in that the fluid coupling is connected to a reaction member of the helical conveyer, without a gear transmission.

5. A centrifuge according to any one of claims 1 to 4, in which the first coupling part comprises a first set of disc-shaped plates having central openings attached non-rotatably to the inside of the housing and having equal distances, and a second coupling part comprising a second set of disc-

shaped plates attached non-rotatably to a rotatable shaft protruding coaxially through the central openings of the first set of plates and having equal distances, by which arrangement the two sets of plates are mounted alternately in the axial direction having basically equal distance between plates, characterised in that the inter-plate distances of one set of plates is larger than the thickness of the plates of the other set of plates, and in that the first and/or the second set of plates are attached in an axially displaceable manner to the housing respectively to the shaft.

6. A centrifuge according to Claim 5, characterised in that the inner or the outer or both plates of each part are separated by springs in such a way that the distance between at least one of the sets of plates are kept at equal distances to each other.

7. A centrifuge as claimed in Claim 5 or Claim 6, characterised in that the plates are alternately splined to input and output shafts.

8. A centrifuge according to any on of Claims 1 to 7, characterised in that the fluid coupling is fully or partly filled with a viscous liquid with high viscosity index and high coefficient of thermal expansion, such as silicone oil.

9. A centrifuge according to any one of Claims 1 to 8, characterised in that the characteristic of the fluid coupling is controlled and varied according to a preset optimization pattern through the control of the temperature of the fluid

coupling and the fluid contained therein, by use of a cooling medium such as air, liquid, or liquid mist, applied onto the outside faces of the fluid coupling.

10. A centrifuge as claimed in any one of Claims 1 to 9, characterised in that the plates are enclosed in a sealed compartment capable of withstanding high internal pressures.

11. A centrifuge as claimed in Claim 10, characterised in that the plates are perforated to ease the exchange of fluid between the plates.

12. A centrifuge as claimed in Claim 6, and any claim appended thereto, characterised in that a piston mechanism is provided to compress the springs, when the fluid expands.

13. A centrifuge according to any one of Claims 1 to 12, characterised in that control of the torque characteristic of the fluid coupling is provided by a pressurising system connected to a sealed-off coupling housing containing fluid and air, giving access for the addition or removal of fluid and/or air during operation, said pressurising system being connected to rotating as well as to stationary fluid couplings, directly or indirectly, by appropriate means.

14. A centrifuge according to any one of Claims 1 to 13, characterised in that control of the torque characteristic of the fluid coupling is provided by a piezo-electrical actuator pressurising system connected to a sealed-off coupling housing containing fluid, giving access to pressurising of the system by

means of electrical signals being transferred to rotating as well as to stationery fluid couplings, directly or indirectly, by appropriate means.

15. A centrifuge according to any one of Claims 1 to 14, characterised in that a control input signal to controlling equipment for the control of the fluid coupling characteristic is a reading of the speed of the conveyer, or the speed of the conveyer relative to the bowl.

16. A centrifuge according to any one of Claims 1 to 15, characterised in that a torque overload safety device is mounted between the fluid coupling and a reaction member of the conveyer drive transmission.

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Application No:	GB 0222013.5	**Examiner:**	Jason Scott
Claims searched:	1-16	**Date of search:**	20 March 2003

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
X	1 & 4	US 4668213	KLOECKNER HUMBOLDT DEUTZ See whole document and in particular column 2, line 61 to column 4, line 59.
A		GB 2069727 A	KLOECKNER-HUMBOLDT-DEUTZ See whole document
X	1 & 4	DE 3409112 A1	HILLER See whole document and in particular Patentanspruche 1 and figure 1.
X	1 & 4	Patent Abstracts of Japan JP 4290562 A KOTOBUKI GIKEN KOUGIYOU (15.10.92) See abstract	

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
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Field of Search:

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Worldwide search of patent documents classified in the following areas of the IPC^{7} :

B04B; F16D; F16H

The following online and other databases have been used in the preparation of this search report :

ONLINE: WPI, JAPIO, EPODOC